



'Alarm' and 'Danger' Criteria in Foot Temperature to Prevent Heat Stroke in Workers Wearing Personal Protective Clothing

Joo-Young LEE^{1,2*}, Kouhei NAKAO¹, Ilham BAKRI^{1,3} Yutaka TOCHIHARA¹

¹ Department of Human Science, Kyushu University, Japan; ²Japan Society for Promotion of Science (JSPS); ³ Engineering Department, Hasanuddin University, Indonesia

Backgrounds



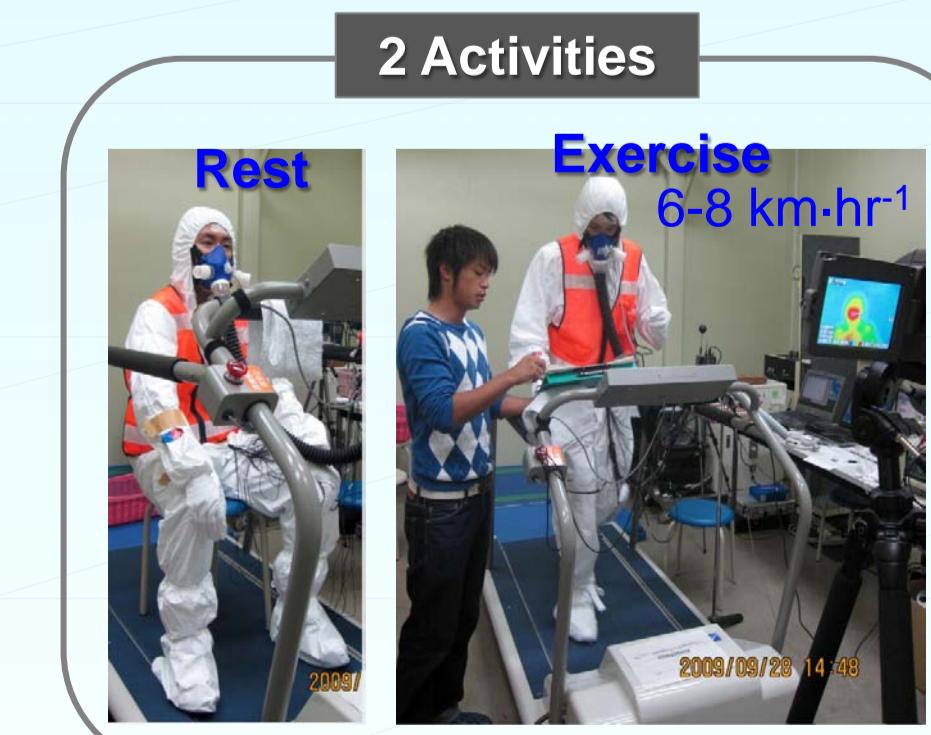
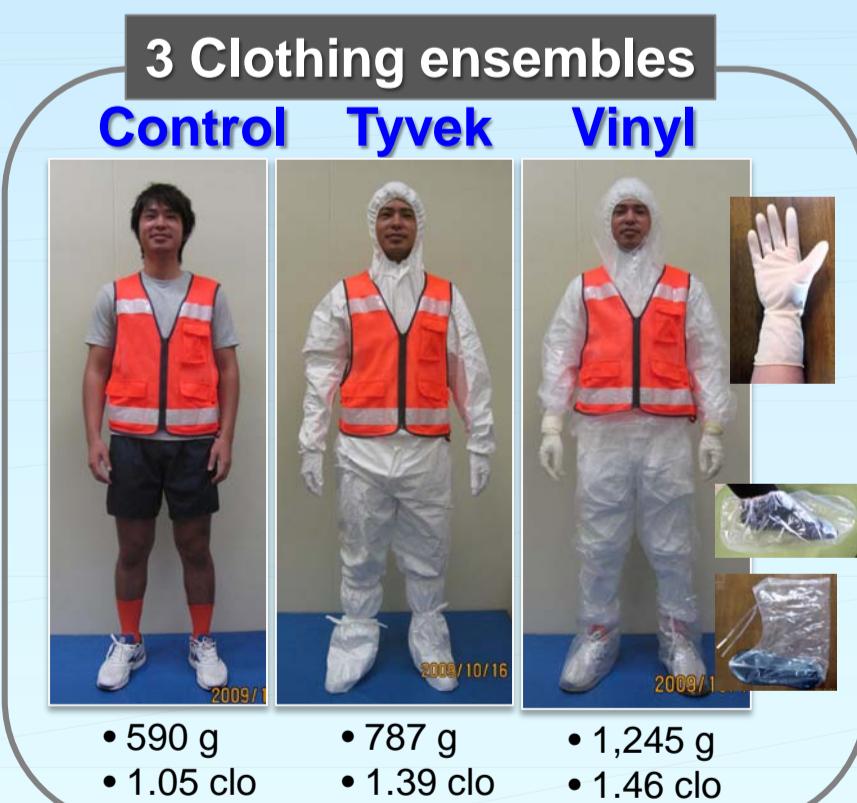
■ Workers wearing personal protective equipment (PPE) in hot environments often encounter severe heat stress. To prevent heat stroke, numerous criteria have been put forth as guidelines: ISO 7243 (Wet Bulb Globe Temperature Index, WBGT) set "Safe" WBGTs.: ISO 7933 (2004) provides physiological criteria for determining the maximum allowable exposure. However, the real-time monitoring of physiological variables during working is relatively less feasible for workers equipped with full protective clothing. To facilitate the assessment of the thermal state of PPE-workers, the development of **non-invasive and simpler measurements** is needed as a valid criterion.

■ **Purpose:** Investigation of the feasibility of foot temperature as a non-invasive and simpler criterion to assess the heat strain of PPE-workers.

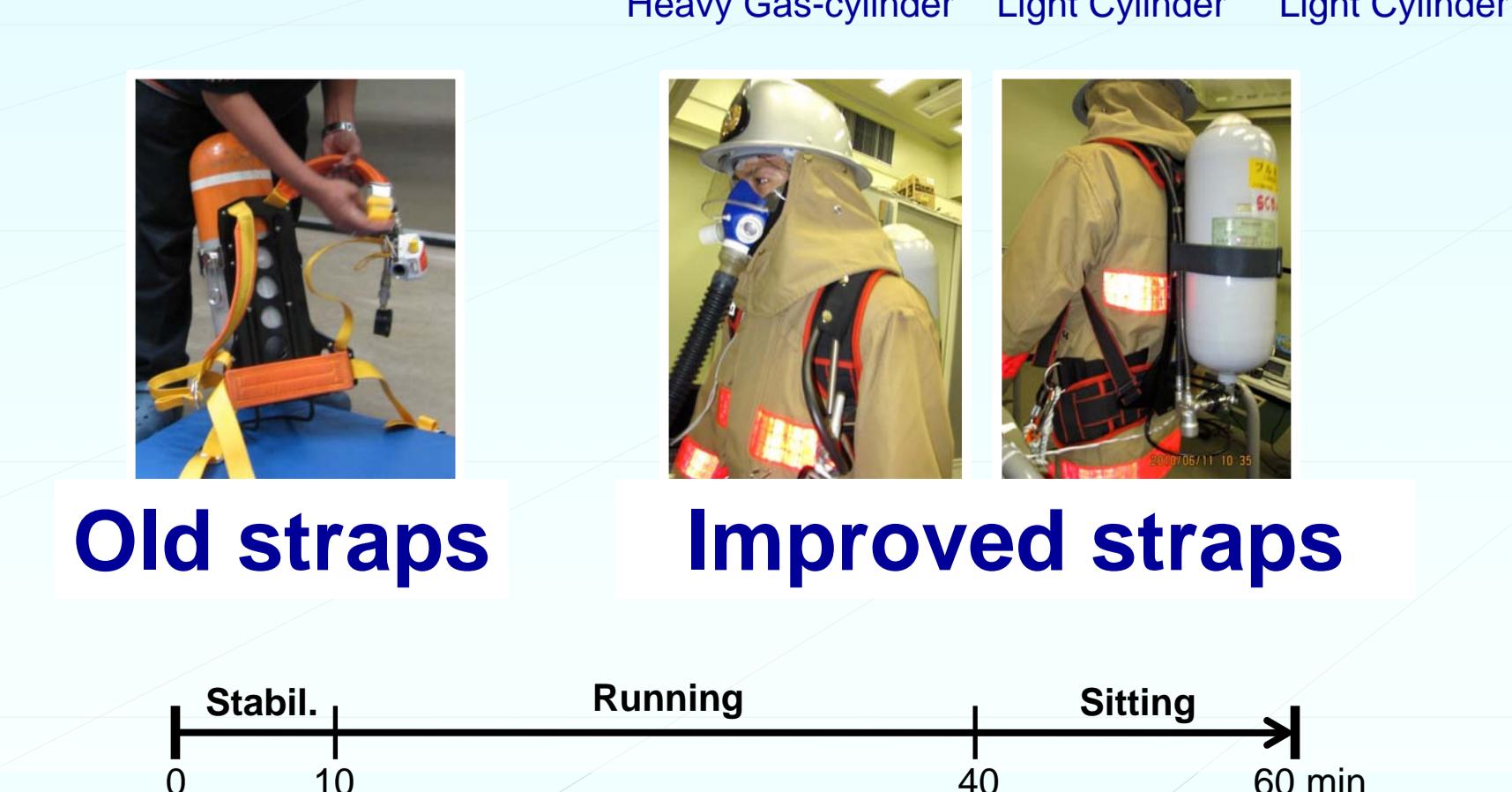
Methods

■ A total of **20** experimental conditions through **2** series of studies with 16 subjects (8+8 subjects)

○ **[Series 1] 12 conditions**
= three clothing ensembles × two air temp. (25 & 32°C, 50%RH) × two activities



○ **[Series 2] 8 conditions**
= Four types of firefighter's PPE × two air temp. (22 & 32°C, 50%RH) × one activity



Measurements

: Skin temp. on 11 sites (2s), Rectal temp: T_{re} (2s), Heart rate (2s), Total sweat rate, Thermal sensation (10min), Thermal comfort (10min).

Calculation

: Physiological Strain Index (PSI)

Results

■ T_{foot} reached T_{re} for the cases where Tyvek coverall was worn at 32°C.

■ For Vinyl condition at 32°C, T_{foot} finally exceeded T_{re} during exercise.

■ In most cases, mean T_{sk} was lower than T_{foot} .

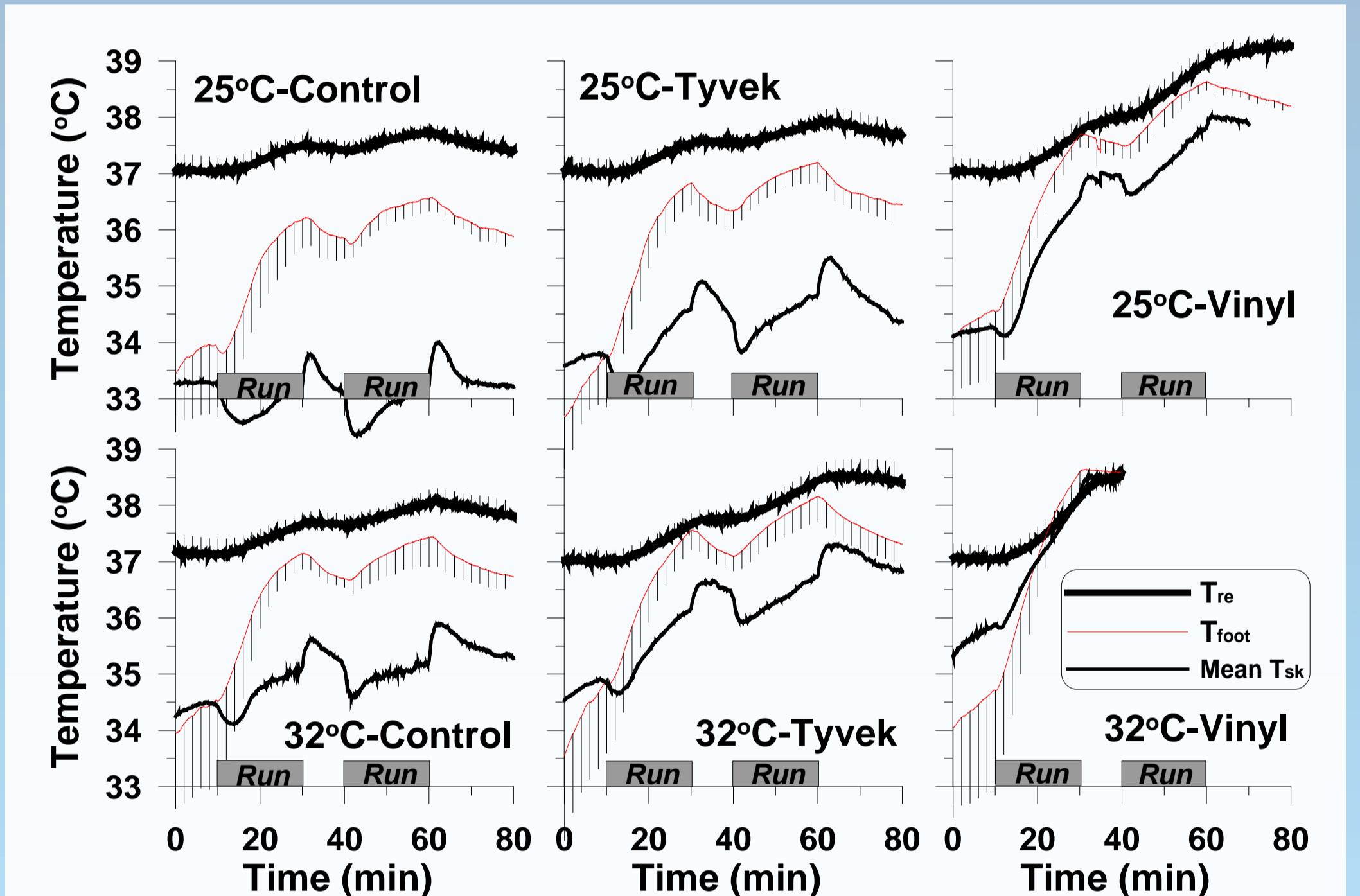


Fig. 1. [Series 1] Time course of rectal (T_{re}), foot (T_{foot}) and mean skin temperatures (mean T_{sk}) during exercise.

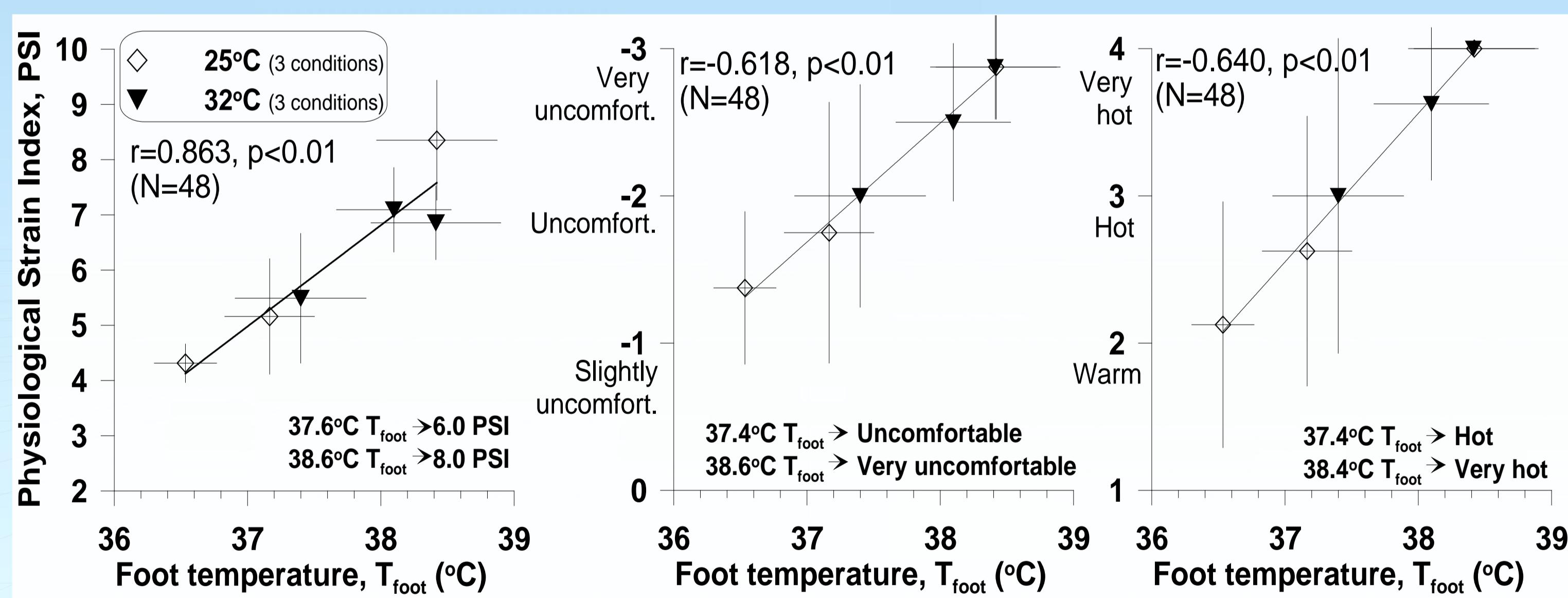


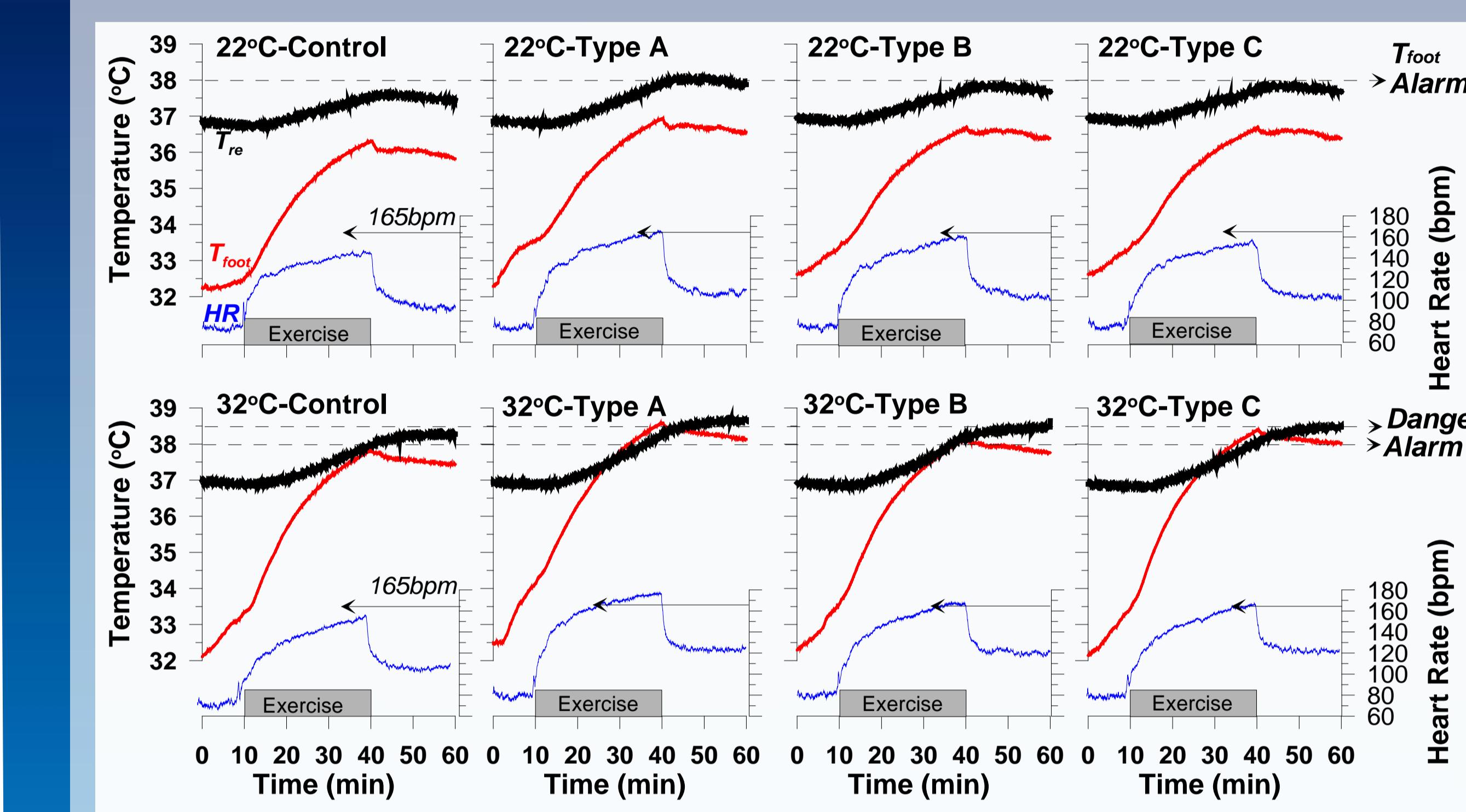
Fig. 2. [Series 1] Relationships of foot temperature with physiological strain index (Left), thermal comfort (middle), and thermal sensation (Right)

■ **PSI:** T_{foot} of 37.6°C & 38.6°C → PSIs of 6.0 & 8.0, respectively

■ **Thermal comfort:** T_{foot} of 37.4°C & 38.6°C → 'uncomfortable' & 'very uncomfortable'.

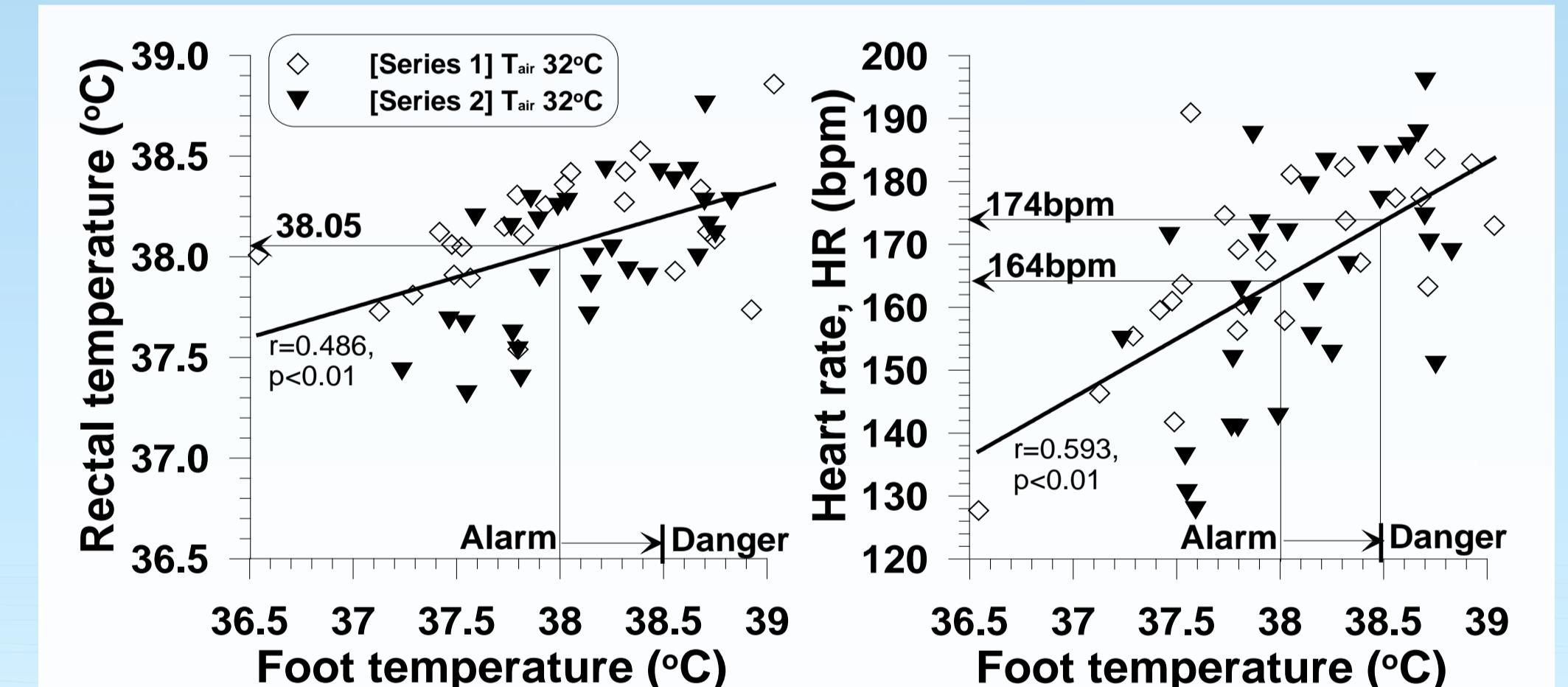
■ **Thermal sensation:** T_{foot} of 37.4°C & 38.4°C → 'hot' & 'very hot'

■ T_{foot} of 38.5°C was set as a '**Danger**' level. For an initial warning value (**Alarm**), T_{foot} of 38.0°C was tentatively determined from the half value between 'uncomfortable' and 'very uncomfortable', 'hot' and 'very hot'.



■ The 'Alarm' and 'Danger' criteria in T_{foot} were then evaluated with new data set drawn from Series 2 (Fig. 3).

■ **Fig. 4 (Left):** The point of showing the identical value between T_{foot} and T_{re} was 38°C. This indicates that as T_{foot} rises up to 38°C, T_{foot} then becomes greater than T_{re} , which means that temperature distribution between the core and shell is reversed at the T_{foot} of 38°C.



Summary and Conclusions

- T_{foot} of 38.0 and 38.5°C were determined as Alarm and Danger criteria, respectively.
- The Alarm level was set at the point that T_{foot} reached rectal temperature during exercise.
- The Danger level was determined at the moments that extreme subjective perceptions were given (very uncomfortable, very hot, and very hard).
- The Alarm and Danger criteria that derived from T_{foot} are valid for workers wearing full protective clothing (including protective boots) in hot environments, but cannot be applied to workers wearing light work wear in thermal neutral environments.